Using a Tracer Gas to Measure Turbine Rim Seal Performance

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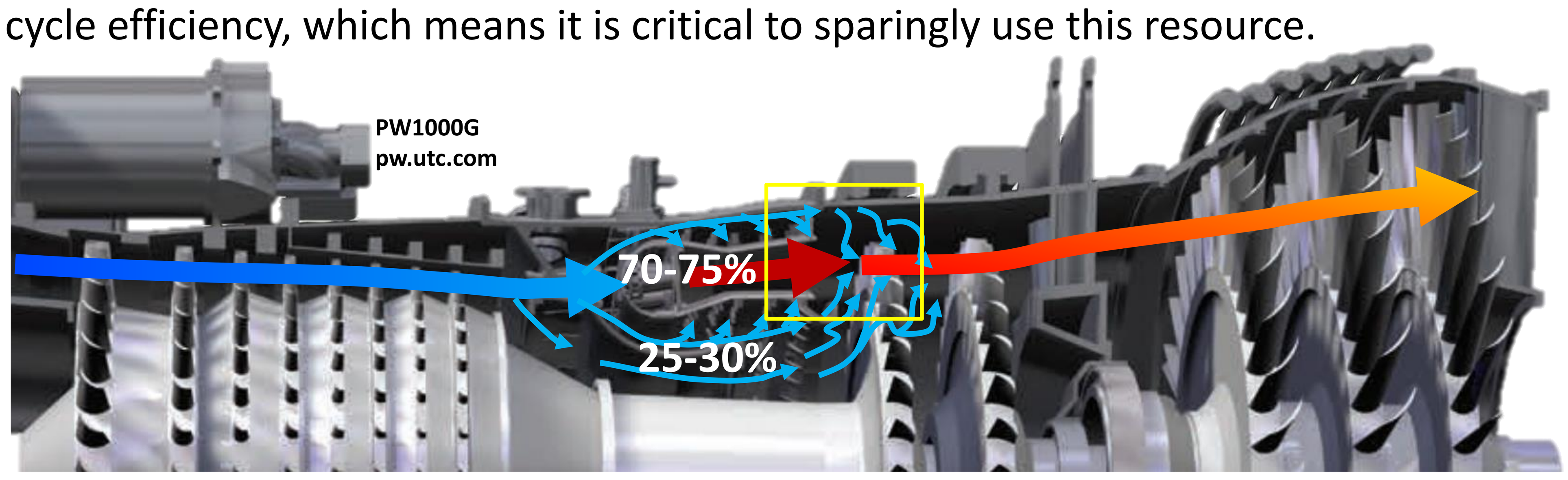
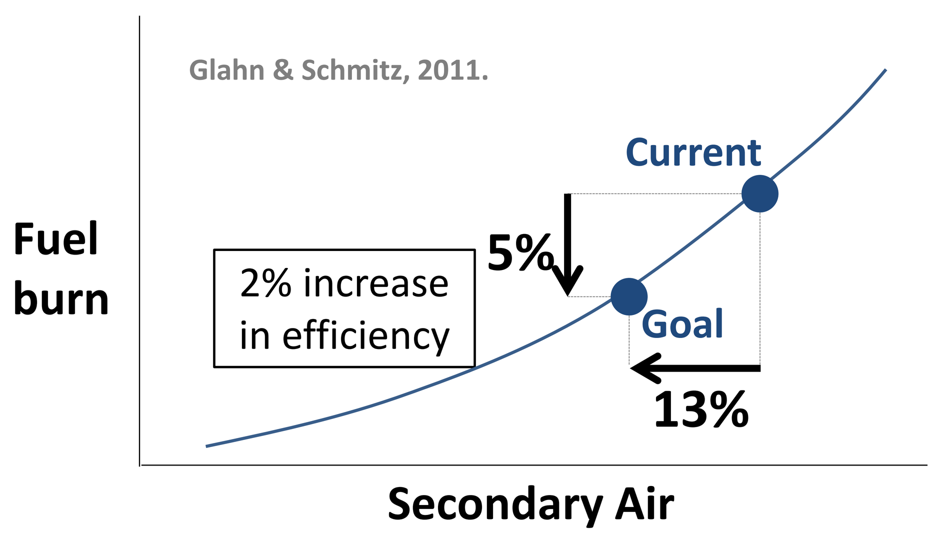
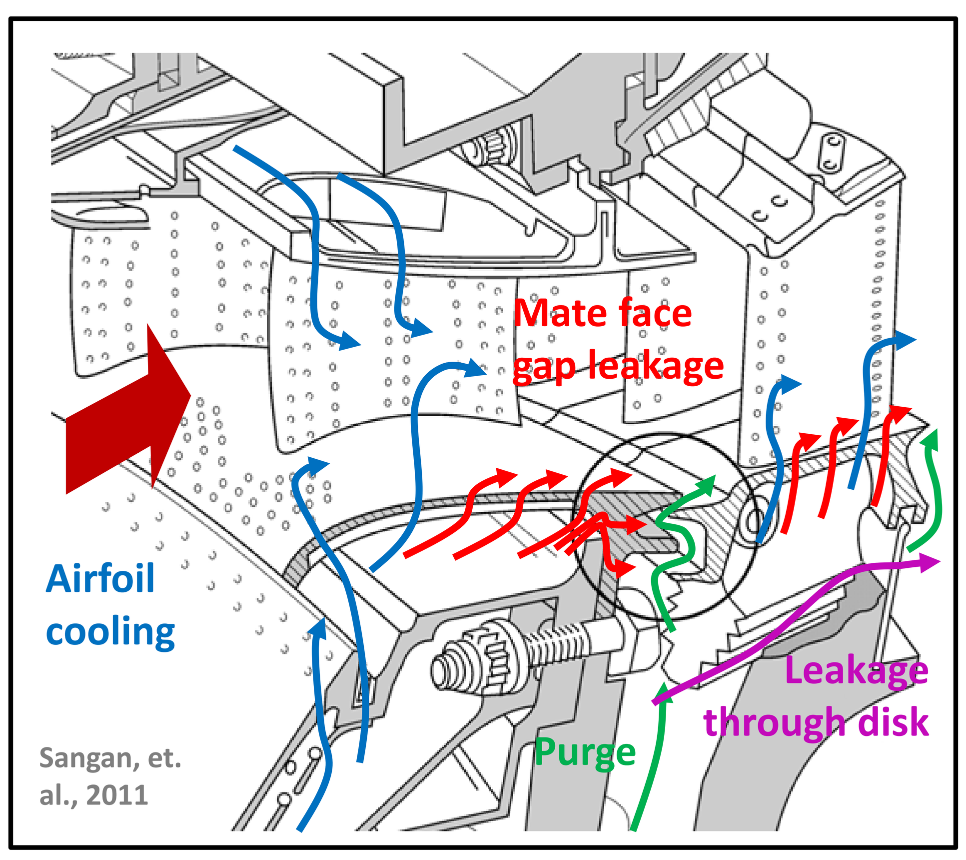
Motivation and Objective

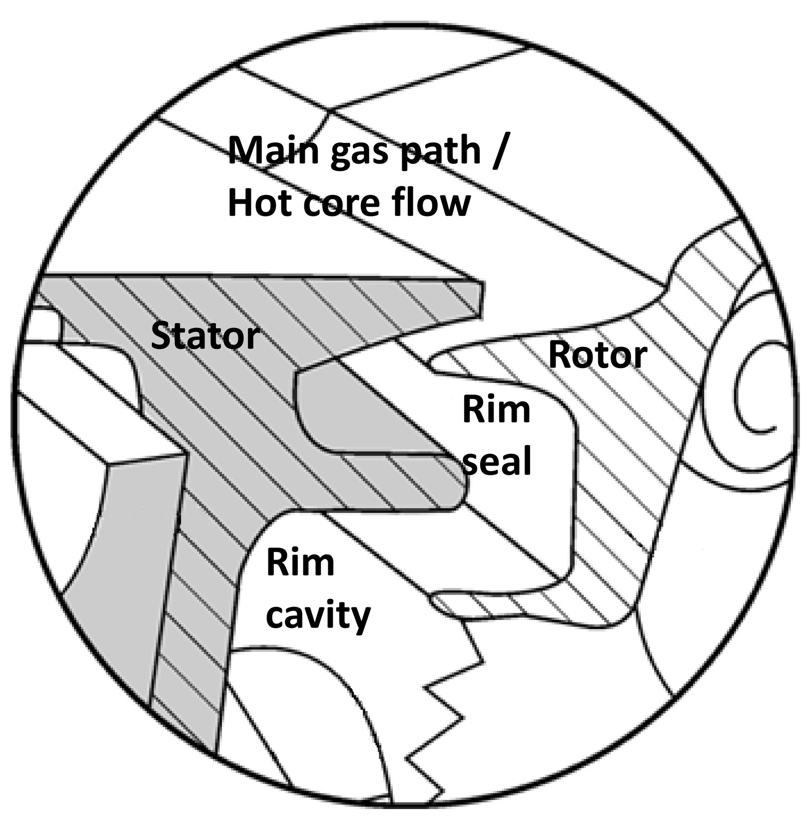
Secondary air is used for cooling and purging in the hot section of a gas turbine engine to maintain component durability. Using secondary air, which is bleed air from the compressor, results in a parasitic loss in terms of an engine's thermodynamic cycle efficiency, which means it is critical to sparingly use this resource.





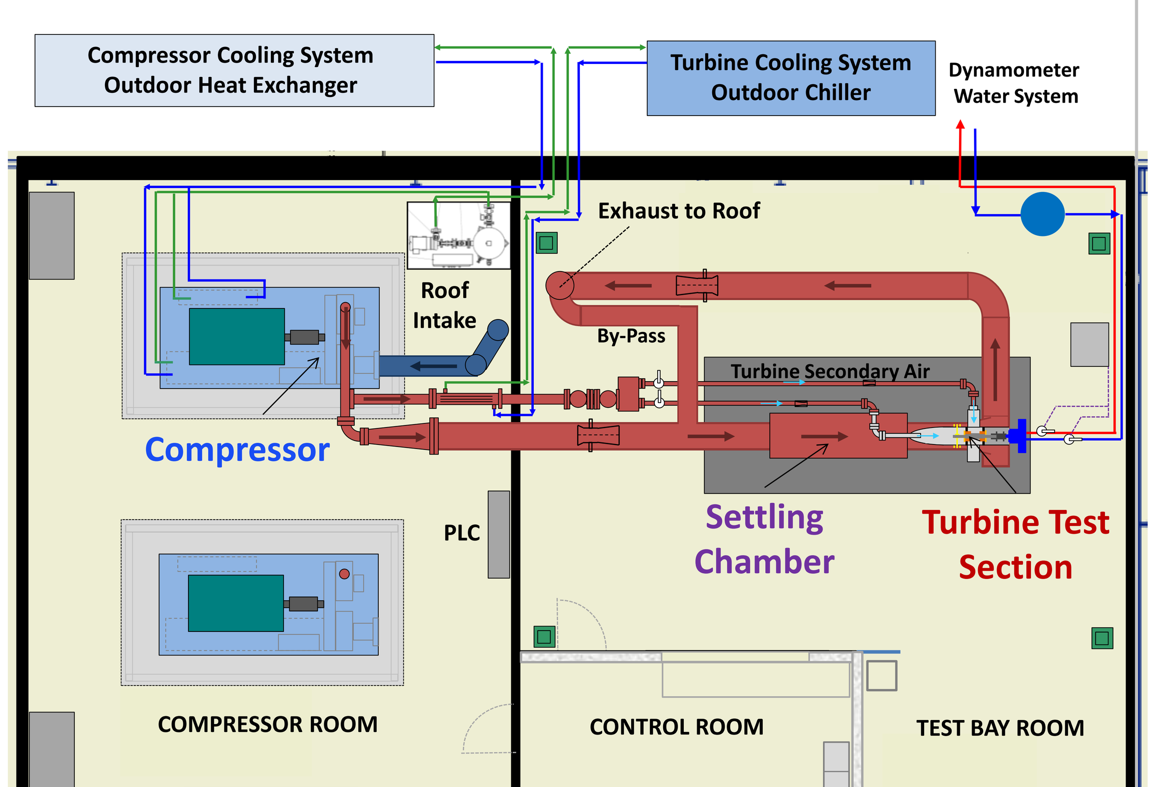
Of specific interest to this research are the rim seals between the stationary vanes and rotating blades and the gaps between adjoining airfoils. The rim seals are intended to reduce the needed secondary air that prevents hot core flow from entering uncooled cavities below the rim seal.



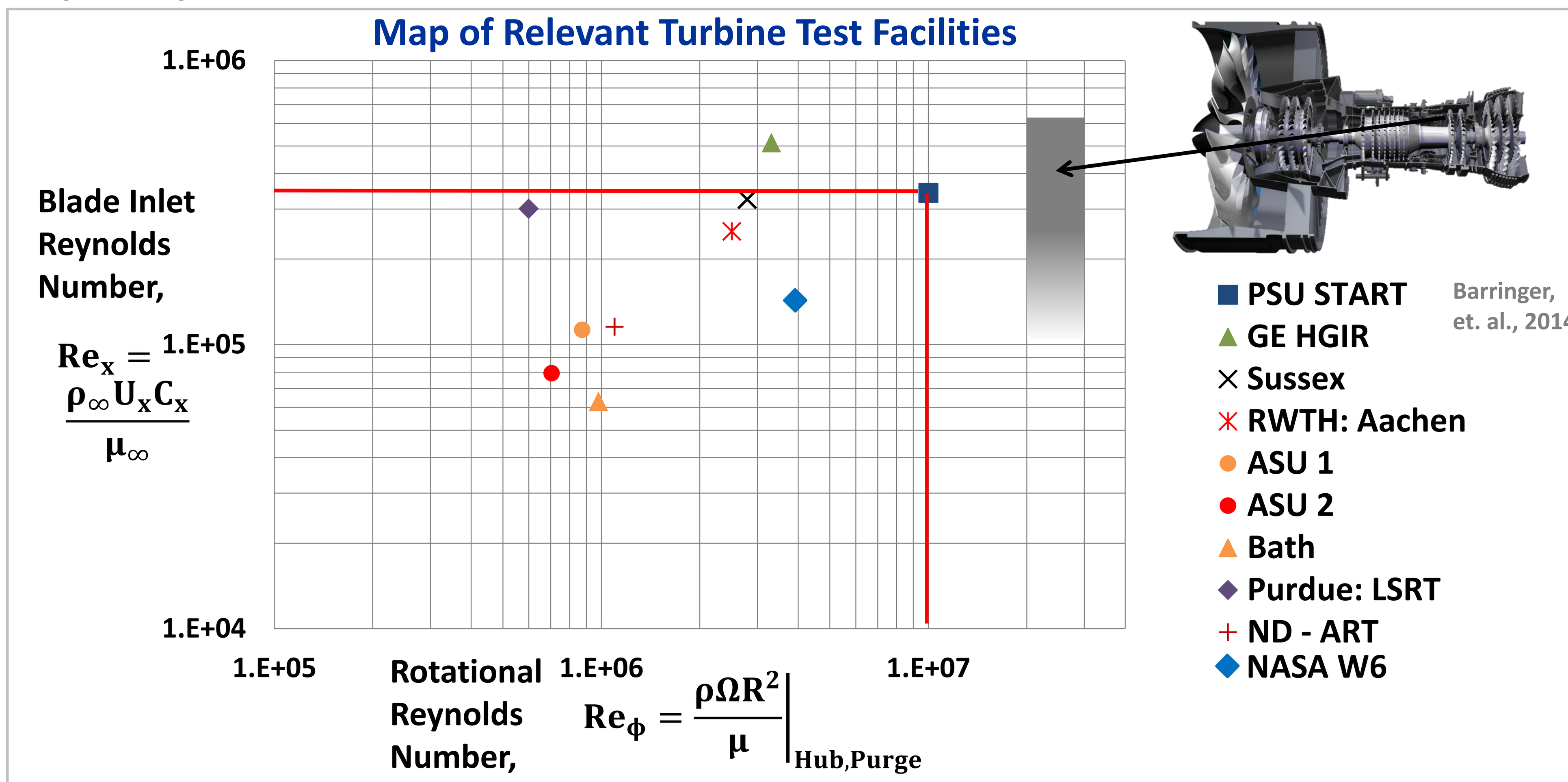


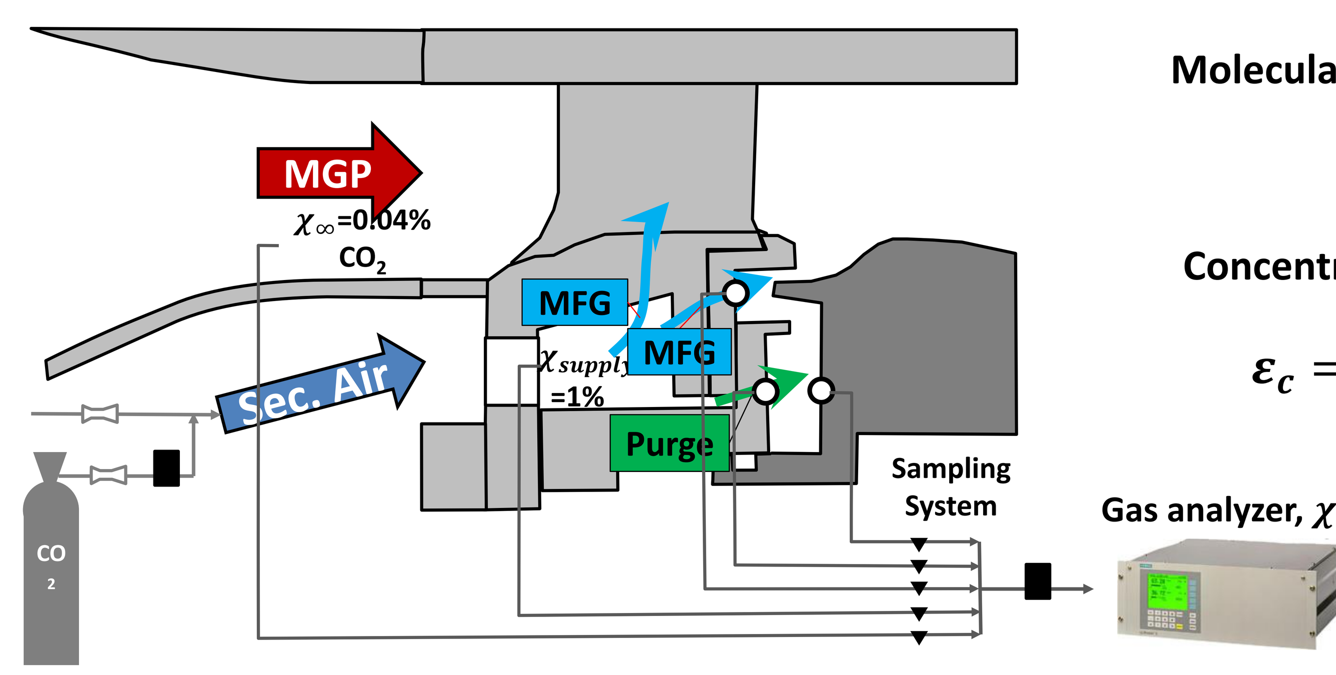
Experimental Approach

Gas concentration measurements were made on a true scale, half-span, high pressure turbine vane in the START rig at engine-relevant conditions.



Map of Relevant Turbine Test Facilities





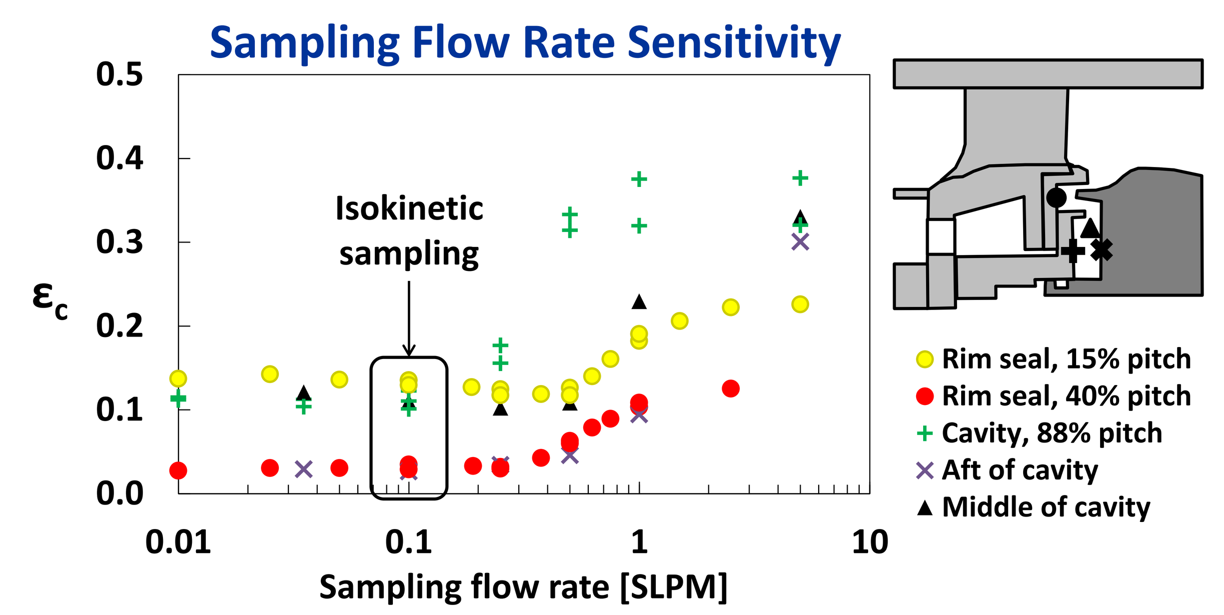
Molecular ≈ Thermal diffusion

Concentration Effectiveness:

$$\varepsilon_c = \frac{\chi - \chi_\infty}{\chi_{supply} - \chi_\infty}$$

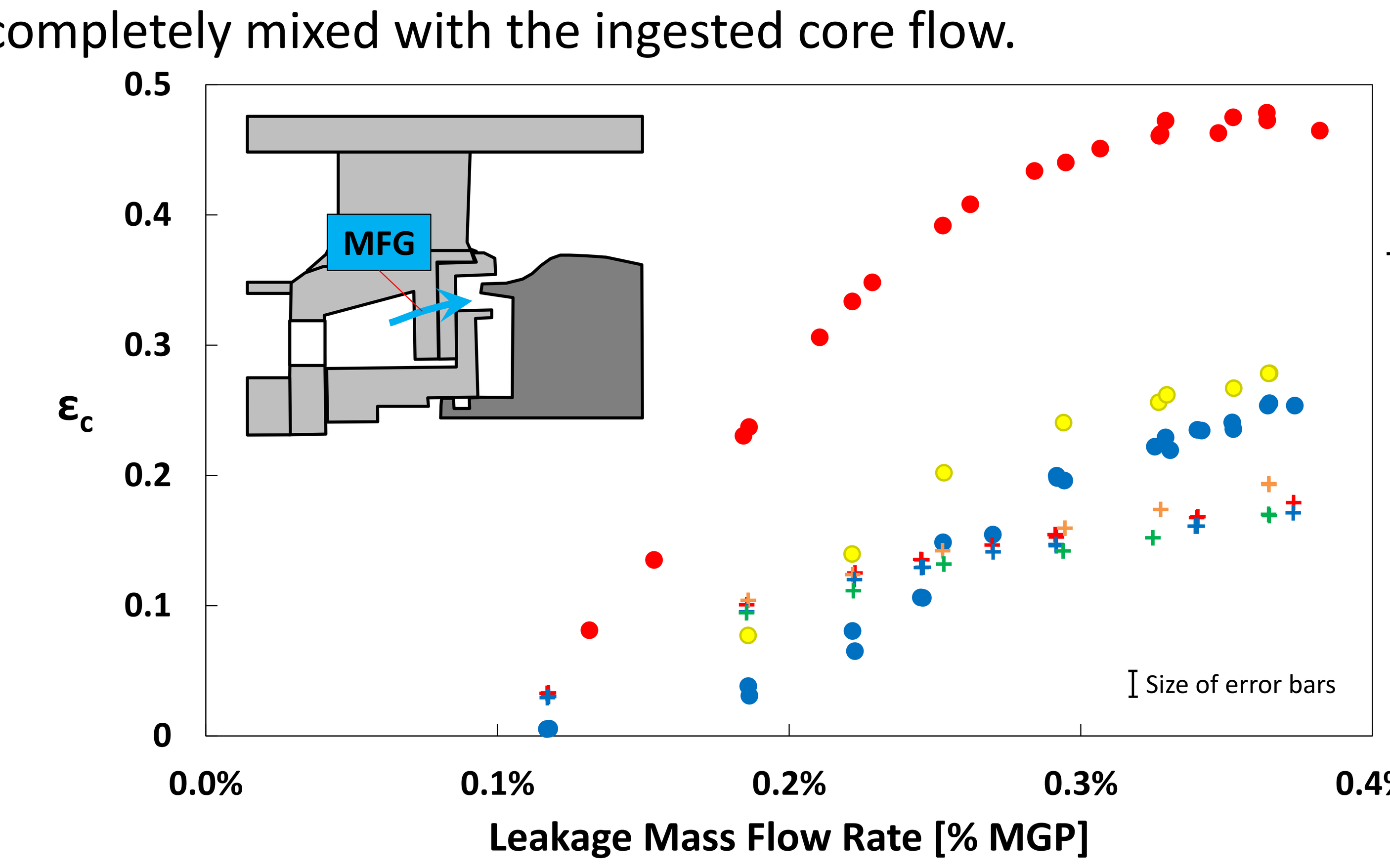
Seeding the secondary air with CO_2 and sampling in the test section at isokinetic conditions results in concentration effectiveness in the rim seals and cavities.

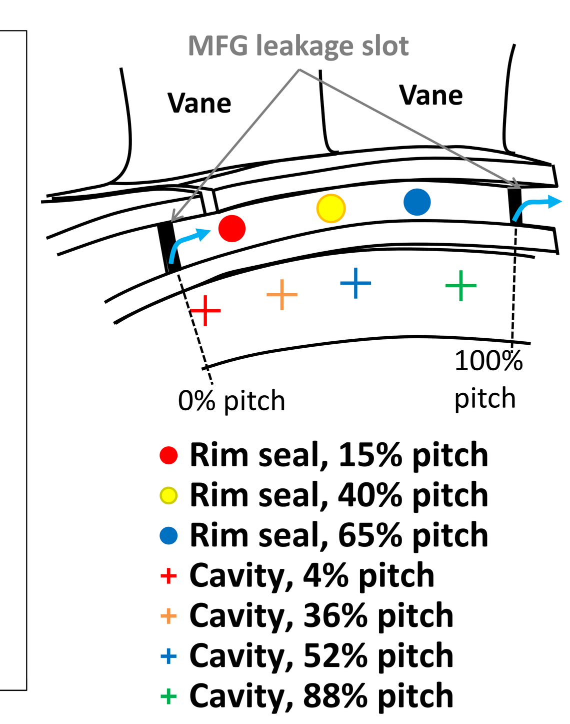
Sampling Flow Rate Sensitivity



Results

Concentration effectiveness in the rim seal is significantly higher closer to the MFG leakage slot, and decreases as it mixes with ingested core flow. Deeper in the cavity the effectiveness is uniform circumferentially, indicating the MFG leakage flow has completely mixed with the ingested core flow.





Summary and Conclusion

The data acquired through these experiments will be used to develop new models to better predict rim seal performance for engine hardware at engine-relevant conditions. The models will be used to design better rim seals in next generation gas turbines, which will result in a reduction in secondary air, fuel burn, and emissions.

References

[1] PW1000G, pw.utc.com.
[2] Glahn, A., and Schmitz, J., 2011, PW Report.
[3] Sangan, C. M., Zhou, K., Owen, J. M., Pountney, O. J., Wilson, M., and Lock, G. D., 2011, "Experimental Measurements of Ingestion Through Turbine Rim Seals: Part 1—Externally-Induced Ingress," ASME Paper No. GT2011-45310.
[4] Barringer, M., Coward, A., Clark, K., Thole, K., Schmitz, J., Wagner, J., Alvin, M. A., Burke, P., and Dennis, R., 2014, "Development of a Steady Thermal Aero Research Turbine (START) for Studying Secondary Flow Leakages and Airfoil Heat Transfer," ASME Paper No. GT2014-25570.